DETERMINATION OF METEOROLOGICAL CORRECTIONS ON THE RANGES OF GUNS.[1]

By WALDEMAR NOLL, Proof Assistant.

[Dated: Aberdeen Proving Ground, Md., Jan. 26, 1920.]

SYNOPSIS.—A projectile in its flight spends more time in the upper part of the trajectory because of its lower vertical velocity, so that when correcting for range and deflection the winds in the upper regions have more time to affect the range or deflection of the projectile and should be given more consideration or weight than the winds lower down. The less dense air composing these upper winds and the decreased horizontal velocity are other factors that must be taken into consideration in order to properly determine the weight that the winds at various heights should be given.

The resistance offered a projectile in its flight varies with the density of the air, other factors being constant. The density aloft is computed from values of pressure and temperature determined from airplane flights. The ratio of observed to normal is then computed and used in making the corrections.

A change in the velocity of sound arising from a change in temperature has the effect of changing the air resistance law of a projectile; hence changing the range of a projectile. Ballistic temperature is computed from values obtained from airplane observations of temperature and by the use of temperature weighting factor curves. These curves are of such a nature that the ballistic temperature may be lower than the lowest actual temperature.

INTRODUCTION.

In the range tables for the various guns the ranges are given for normal meteorological conditions of wind, air density, and air temperature. When these normal conditions do not exist, which is nearly always the case, it becomes necessary to correct range and deflection to the existing meteorological conditions.

Previous to 1917, the principal corrections for meteorological conditions were made, using surface conditions. But surface meteorological conditions seldom represent the upper air conditions prevailing through the whole trajectory, as the winds aloft usually have different velocities and directions from those on the surface, while the decrease of density and temperature as the altitude increases is very irregular. Consequently, the existing meteorological conditions aloft must be taken into account in making the corrections. Because of the many factors that affect a trajectory, the meteorological conditions at different altitudes must be specially considered or weighted in order to properly make the corrections for range and deflection. To properly consider these factors, terms have been introduced known as *ballistic meteorological conditions, namely,* ballistic wind, ballistic density, and ballistic temperature. A ballistic meteorological condition is an imaginary one, which has the same effect on a trajectory as the true *conditions that do exist within the limits of the trajectory.*

It has been with the aid of ballistic meteorological conditions of this sort that the new range tables have been constructed. Therefore, it is also necessary, when these tables *are used, to take range and deflection corrections* for the existing meteorological conditions, using similar methods.

In order to clearly understand the corrections for wind it is necessary to consider briefly a few facts about the flight of a projectile. A projectile in its flight spends more time in the upper part of the trajectory because of its lower vertical velocity, so that when correcting for range and deflection the winds in the upper regions have more time to affect the range or deflection of the projectile, and should be given more consideration or weight, than the winds lower down. The less dense air composing these upper winds and the decreased horizontal velocity are other factors that must be taken into account in order to properly determine the consideration or weight that the winds at various heights should be given. The weight that should be given the winds at different altitudes are found in wind weighting factor tables that are incorporated in the range tables for the various guns. Using the factors from these tables and the wind velocities obtained from the Meteorological Section, a fictitious or resultant wind is computed which is used in making the range and deflection corrections for wind. The wind is known as ballistic wind and has the same effect in changing the range or deflection as the winds that actually exist. Ballistic range and cross winds must be computed using the respective range and cross wind weighting factors.

The weighting factors are obtained from weighting factor curves which have been computed for the various guns by a series of differential corrections.

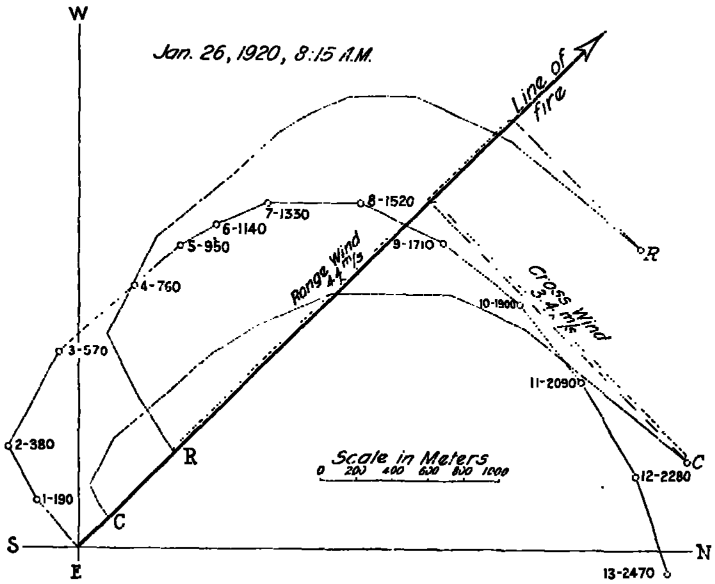

FIG. 1.—Determination of range and cross winds.

The velocities and azimuths of the winds aloft for equal zones of altitude, such as 250 meters, are determined by observing the flights of pilot balloons by theodolites. For the particular gun to be fired and for the definite range to be obtained each 250-meter zone up to the maximum ordinate of the projectile has a certain weighting factor for both range and cross wind. The weighting factors for the various zones are then multiplied by the wind velocities for the corresponding zones, and two columns of values established. On the plotting board the line of fire is laid out. (See fig. 1.) Beginning at any convenient points on the line of fire two lines are drawn parallel to the azimuth of the wind for the first zone. On these lines are measured out, respectively, the products of range and cross wind weighting factors and velocities. From the two points determined two additional lines are drawn parallel to wind azimuth of zone two and on them are laid out the products for the second zone. This is continued until the values for all the zones have been plotted. From the final points determined, perpendiculars are dropped to the line of fire, thereby completing the polygons. In the range-wind polygon the distance from the first point on the line to the foot of the perpendicular, after being reduced to

[1] This paper is not in anywise to be taken as an official statement from the Army.

scale, equals the ballistic range wind and is given in meters per second. If this wind tends to increase the range it is positive, and if it tends to decrease it is negative. In the cross-wind polygon the length of the perpendicular itself gives the ballistic cross wind. If the wind tends to deflect the projectile to the right it is positive; to the left, negative. The values of ballistic winds are then used in correcting the ranges.

BALLISTIC DENSITY.

The resistance offered a projectile in its flight varies with the density of the air, other factors being constant. A decrease in density corresponds to an increase in range and vice versa. Consequently it is necessary to know the density of the air to the height to which the projectile rises, in order to properly determine the ranges. After the values of pressure aloft, vapor pressure aloft, and temperature aloft are obtained by use of airplanes or kites, the densities are computed and plotted against true height. From the density curve thus drawn the densities for every 250 meters altitude are read off.

We are now ready for a consideration of ballistic density, "ballistic density may be defined as an average or resultant ratio of observed density to normal density, determined by properly weighting the ratios of observed density to normal density, throughout the zone under consideration—that is, from the surface to the height of the maximum ordinate of the trajectory for which the ballistic density is being obtained. Normal surface density is taken as 0.001206 grams per cubic centimeter. The ratio of normal density at an elevation of y meters, to normal surface density is equal to $e-.0001036\ y$.

When the time of the aeroplane or kite flight is the same as that of the firing of the gun, the density chart may be used as it stands. Densities at intervals of 250 meters from the surface to the height of the maximum ordinates are read off, and normal densities for the corresponding heights are subtracted from them. The differences thus obtained may be averaged directly. But the question of properly weighing these ratios comes in at this point. Fortunately nearly all weighting may be neglected, as the weighting factors are, in general, nearly the same for all zones except the top. The correct weighting if approximately obtained by giving the bottom and top zones double the weight received by the rest. This is directly accomplished by simply averaging the differences as they stand, inasmuch as they are the differences at each height and not of each zone, as already explained.

This average thus obtained is the ballistic density, and is used in obtaining a proper correction for an observed range.

When the time of the firing does not coincide with the time of the observation, a slight change in the density chart may be necessary. From the surface temperature and pressure at the time of the firing the surface density is figured and plotted as a point on the chart. From this point a line is drawn which is made to converge gradually with the density curve. The density curve with this correction is more or less a matter of judgment. From a study of density aloft, it is apparent that the density changes from hour to hour are usually greatest at the surface, decreasing with altitude, and become very small at the height of 1,500 meters in winter and 2,000 meters in summer.—[Extracted from memorandum by O. P. Camp.]

BALLISTIC TEMPERATURE.

It is well known that the change in the velocity of sound arising from a change in temperature has the effect of changing the air resistance law [of a projectile], principally in the neighborhood of the velocity of sound, and hence of changing the range of a projectile whose velocity at some part of its path passes through or strikes into the velocity of sound regions. [Extract of memorandum by Dr. Graustein.]

Ballistic temperature used in making the corrections for range may be defined as a resultant or fictitious temperature obtained by properly weighting the true temperatures for every 250 meters from the surface of the earth to the height of the maximum ordinate.

Accordingly, two range tables for the same gun and projectile, made up on the basis of firings during opposite seasons of the year and not corrected for temperature, might well differ by as much as 3 per cent. In fact, discrepancies between -millimeter shrapnel tables have been traced precisely to this cause. [Extract of memorandum by Dr. Graustein.]

In computation of ballistic winds, results approximately correct may be obtained without weighting the true winds in the various zones; ballistic density can be obtained without weighting the true densities; but ballistic temperatures must always be determined by weighting the true temperatures. A study of Temperature Weighting Factor curves shows that the factors for the lower zones are negative. Because of these negative values it is entirely possible to have a ballistic temperature lower than the lowest true temperature. It is thus seen that some average or mean temperature would not be correct.

APPLICATION OF METEOROLOGY TO GUNNERY.[1]

By ERNEST M. WEDDERBURN.

Space will not permit a complete review of the material covered in this paper of 22 quarto pages, which has been issued by the Experimental Establishment, Shoeburyness, 1919; but those interested in the subject will find it an interesting and valuable reference. It consists essentially of three parts, the first treating of meteorological variations in still air, the second, of air in motion, and the third, of practical applications. There is a preface by Lieut. Col. Ernest Gold, in which the progress of the relations between the artillerist and the meteorologist is traced through the war. The concluding words of the preface give very adequately the value of the research of which the paper is a report:

"As may be expected, the information so obtained has other uses: It furnishes aviators with the means of accurate navigation; it throws light on many of the apparent idiosyncrasies of meteorological charts; and it gives the weather forecaster practical certainty in many situations which would otherwise be almost guesswork.

"The need of an authoritative summary of the results achieved, both in practice and in theory, and of the practical problems still awaiting solution, has been apparent for some time, and meteorologists and gunners will both benefit by Capt. Wedderburn's exposition."—*C. L. M.*

[1] A briefer discussion is published in the Journal of the Scottish Meteorological Society, 1919, vol. 18, 3d ser., no. 36, pp. 86–92.